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Modernization Problems in the Soviet Airframe Industry

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A Research Paper

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Modernization Problems in the Soviet Airframe Industry [redacted] 25X1

A Research Paper

This paper was prepared by [redacted] of the Office of Soviet Analysis. Comments and queries are welcome and may be directed to the Chief, Defense Industries Division, SOVA, [redacted] 25X1 25X1

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Modernization Problems in the Soviet Airframe Industry [redacted] 25X1

Summary

Information available as of 1 June 1985 was used in this report.

Until the early 1970s, production of successive generations of Soviet aircraft did not require rapid advances in manufacturing technologies. Aircraft were made largely from sheet metal and other materials that were easy to fabricate on tools typical of those used in US plants of the 1930s. In the late 1950s and 1960s, however, Western industries produced aircraft, such as the B-58, F-111, and SR-71, that had much better performance than contemporaneous Soviet models. This production depended partly on new manufacturing techniques that required equipment for fabricating parts made of high-strength titanium and stainless steel and for machining complex aerodynamic shapes. [redacted] 25X1

The Soviets required similar improvements in manufacturing technologies to keep pace, but their aircraft industry faced three major problems in the late 1960s:

- Machine tools in aircraft plants were outdated, and most were not as capable as those in the West.

- Engineers expert in manufacturing technology were generally not readily available to assist plant staffs, from which they were separated both administratively and geographically. Western engineers and manufacturing personnel usually are colocated and cooperate closely in developing and perfecting new manufacturing techniques.

- The stock of obsolete plant and equipment increased, because Soviet capital investment practice had favored building new facilities at the expense of renovating established ones. [redacted] 25X1

To overcome these problems and meet the challenge posed by advanced Western aircraft, the Soviets began to modernize their 16 aircraft factories. We believe that most, if not all, have been upgraded since 1970. Some of the improvements were tied to the introduction of new production programs, because Soviet procedures for developing new systems usually require the development of dedicated tooling and equipment. The eight dedicated facilities undertaking the most ambitious production programs, such as the TU-160 Blackjack and the AN-124 Condor, expanded the most in the late 1970s and 1980s. Other improvements, though, appear to have been part of a more general plan. A substantial amount of modernization has taken place through expansion of existing production facilities and the construction, at Ul'yanovsk, of a modern new plant for the production of wide-bodied aircraft. [redacted] 25X1

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The Soviets also have begun to manufacture aircraft components made of nonmetal composite materials—high-strength fibers bound together in a matrix. Composite aircraft structures are stronger and lighter than those of conventional metal and afford the benefits of greater payload, range, or maneuverability. Composites, however, require processes and manufacturing equipment substantially different from those employed in traditional metalworking techniques. 25X1

Despite some use of improved techniques and composites, fragmentary direct evidence, as well as delays in assimilating new technology, suggests that the modernization program has on the whole proceeded slowly and sporadically. The industry has continued to spend much of its available investment funds on new buildings rather than on replacement of obsolete machine tools. The machine tools available to the Soviet aircraft industry still do not appear to be equal to those manufactured in the West, and, to compensate, the Soviets have turned increasingly to imports of Western manufacturing technology and equipment. The introduction of new technologies, such as composite materials, has been slow, partly because of the conservatism of designers. Finally, the level of technical support for complex manufacturing operations remains poor. 25X1

As a result, Soviet aircraft manufacturing technology appears to be roughly equivalent to US technology of the mid-to-late 1970s. Soviet progress has supported the fielding of substantially improved aircraft, but even recent fighters and heavy transports have lagged the introduction of their US counterparts by five to six years and up to 14 years, respectively. Emigre reporting and Western analyses of Soviet aircraft indicate that manufacturing limitations contributed to these lags. Analysis of new, high-priority aircraft like the IL-86 airbus suggests that production technologies are changing slowly, constraining designers' efforts to improve aircraft performance. 25X1

Despite their efforts to modernize, we believe that the Soviets' progress probably will be slower and more difficult than that of the West. Western aircraft firms are agressively implementing new technologies—new types of composites, superplastic forming and diffusion bonding of titanium, and computer-aided design and manufacturing processes—to obtain stronger, lighter airframes and advanced electronic systems that will improve performance significantly. The Soviets are just learning many of these techniques. Moreover, we believe the strong competition for investment funds makes it unlikely that the USSR will be able to effect the kinds of improvements necessary to bring its plants up to parity with the West. Western progress in new manufacturing technologies together with delays in the Soviet modernization program will, we believe, prevent the USSR from matching the performance of Western aircraft. 25X1

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In addition, without widespread introduction of new manufacturing technologies, aircraft production in the USSR will remain highly labor intensive. The trend toward longer production times and higher unit costs characteristic of recent Soviet attempts to manufacture more complex aircraft is likely to continue. 25X1

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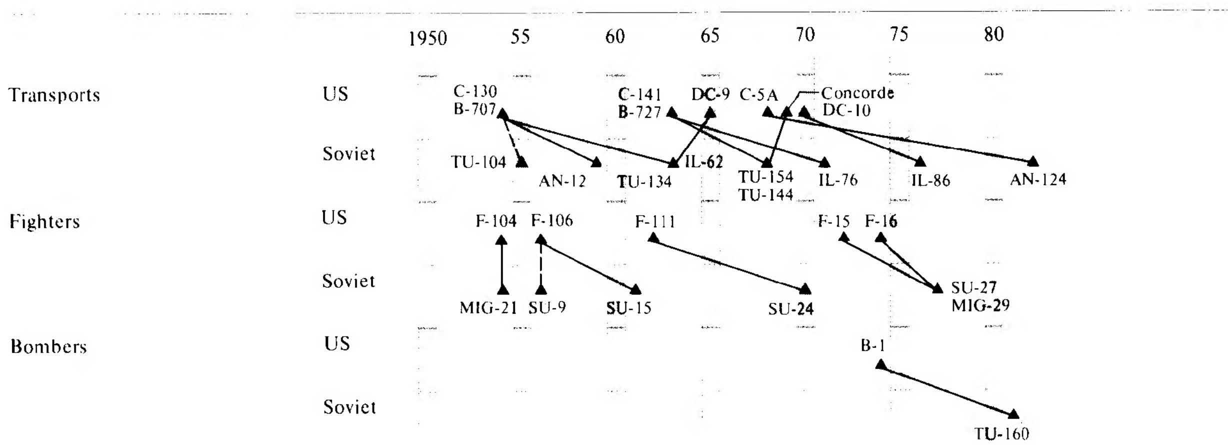
Figure 1
First Flights of Comparable Aircraft



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Modernization Problems in the Soviet Airframe Industry 25X1

Soviet Aircraft Technology

Until the early 1970s the production of successive generations of Soviet aircraft generally did not require sustained, rapid advances in Soviet manufacturing technology. On the basis of detailed examination, Western analysts infer that Soviet aircraft manufactured during the 1950s and 1960s, such as the MIG-19, the MIG-21, and the SU-7 fighters, were designed to be built with relatively simple machine tools and highly labor-intensive manufacturing techniques. They were made mainly of sheet metal and other materials that were easy to fabricate, contained few parts that require complex machining, and incorporated many castings. A Western manufacturing analysis of the MIG-21, for example, revealed that all but one or two parts could have been produced on machine tools found in a typical US aircraft plant of the 1930s. The Soviets attempted to compensate for lagging technology in design and manufacturing with large production runs of their relatively simple and inexpensive aircraft.

In the late 1950s and 1960s, the United States developed aircraft with performance that far exceeded their contemporaneous Soviet counterparts (see figure 1). Improvements in performance were made possible by a broad range of technological advances:

- Lighter yet stronger structures that enabled designers to adopt improved aerodynamics and gave the aircraft the ability to withstand greater loads.
- Engines that had higher thrust-to-weight ratios.
- More capable electronic and weapon systems.

To build these aircraft, Western manufacturers had to develop a variety of new manufacturing technologies and to equip factories with advanced machine tools. They had to learn how to manufacture parts from newly developed, high-strength stainless steel and titanium that required precise heat treatment procedures and sturdier and more accurate machine tools. Factories also had to be equipped with multiaxis machine tools that could efficiently fabricate the complex aerodynamic surfaces of the new aircraft. 25X1

Designing Around Limitations in Production Technology: The MIG-25

To intercept high-speed targets, such as the B-70, the MIG-25 had to fly at speeds higher than Mach 2.5. At these speeds, the leading edges of the wings and other exposed parts reach temperatures high enough to weaken the aircraft's structure. These temperatures are conducted throughout the entire aircraft, causing severe problems for electronic, hydraulic, and other vital systems. To withstand the high temperatures, aircraft designed to fly at these speeds are usually built of titanium or stainless steel, both of which are difficult to form and require carefully controlled manufacturing conditions. 25X1

Western analysts' examination of a MIG-25 in Japan, however, revealed that the Soviets chose to limit the length of time the aircraft could stay at elevated speeds—only long enough for the Foxbat to perform an intercept—rather than build the entire structure to withstand high temperatures. 25X1 *Because of both this compromise and engine limitations, the fighter reportedly can stay at high Mach numbers, that is, above Mach 2.65, for only five minutes. The Mikoyan Design Bureau was thus able to meet the Foxbat's primary mission requirement of intercepting high-speed targets and still use proven production techniques. Similar compromises have been detected in almost every Soviet aircraft available for detailed examination in the West.* 25X1

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Advances in Soviet aircraft system technology and the stimulus of US progress led the Soviets to begin production, in the mid-to-late 1960s, of improved aircraft like the MIG-23 and MIG-25 fighters and the TU-144, IL-62, and TU-154 transports. These

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aircraft were constructed with more high-strength steel and titanium and contained more complex aerodynamic shapes than their predecessors, which made them considerably more difficult to manufacture. Nevertheless, the Soviets generally continued to try to design around their shortcomings in manufacturing technology (see inset, "Designing Around Limitations in Production Technology: The MIG-25"). They produced most of these aircraft in plants that had not been extensively upgraded. They also sought expeditious, cost-effective routes to aircraft production, even if those imposed burdens on the military for increased maintenance and replacement rates (see figure 2).

In building a few aircraft, most notably the TU-144 supersonic transport, the Soviets chose to stress advanced technologies, and they ran into difficulties (see inset, "Pushing Technology: The TU-144 Supersonic Transport"). Close working relationships between design bureaus, research institutes, and the production plants are especially important in such programs to solve the many problems that arise with the introduction of new manufacturing technologies or materials.

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Pushing Technology: The TU-144 Supersonic Transport

Soviet programs often failed when aircraft that required the use of advanced manufacturing practices were designed. Perhaps the best example is the Soviets' effort to build a supersonic transport—the TU-144. Design began in 1963, about two or three years after the start of the MIG-25 Foxbat program. The TU-144 represented a high-priority, "national prestige" program to demonstrate the superiority of Soviet technology. [redacted]

The TU-144 was the first supersonic transport to fly, preceding the Concorde by four months. But it apparently never became sufficiently safe and reliable for the Soviets to trust it for regular passenger service. Because the TU-144 had to cruise at its top speed (Mach 2.3) for long periods, thermal problems were severe and required the use of materials and parts and components able to withstand high temperatures. In their haste to fly the TU-144 before the French completed the Concorde, however, the Soviets attempted to solve these problems as a Western designer would. The Tupolev Design Bureau decided to incorporate a fairly high percentage of titanium in the aircraft, even though Soviet manufacturing technologies for this metal had not yet been perfected. [redacted]

The TU-144, which experienced repeated difficulties during its test program, crashed at the 1973 Paris Air Show. Although no official explanation has been offered, [redacted] *the Soviets were worried about the strength of some of the aircraft's titanium parts. After repeated efforts to perfect the design, the Soviets announced in April 1983 that the program had been canceled. The overall commitment to the TU-144—including the dedication of one of the two Tupolev design teams for at least seven years and the almost complete dedication of the Voronezh airframe plant for six or seven years—suggests it has been one of the most expensive aircraft development projects ever undertaken.* [redacted]

Soviet design bureaus like Tupolev worked without the advantage of such relationships. US aircraft designers faced many of the same problems, such as hydrogen brittlement of titanium and high-strength steel, in the earlier SR-71 and B-58 programs, but they were able to successfully complete them. [redacted] 25X1

The Soviets developed increasingly complex aircraft through the 1970s and into the 1980s: first, the SU-27 and MIG-29 fighters, generally comparable to the US F-15, F-18, and F-16; the TU-160 Blackjack, a counterpart of the B-1; and the AN-124 Condor, comparable to the C-5A (see figure 3). Production of these Soviet aircraft required more advanced manufacturing capabilities. Although we have incomplete information on these aircraft, they appear to have even more complex aerodynamics, and many of the parts are made with new materials such as composites. [redacted] 25X1 25X1

Need for Modernization in the 1960s

The generation of aircraft developed in the 1960s and manufactured in the 1970s challenged Soviet industrial officials to upgrade their manufacturing capabilities. They presided over a large assembly base, with little standardization among plants (see inset, "The Ministry of Aviation Industry," and figure 4). Soviet literature, emigres, and Western travelers indicate that each plant was equipped over the years on a generally opportunistic basis, capitalizing on occasional imports, war reparations, and equipment acquisitions from the aviation industry. Major differences in approach among powerful aircraft design bureaus accounted for differences among the plants under their spheres of influence. The absence of cost-driven competitive pressures meant that plants were not obligated to seek out the most efficient approaches. [redacted] 25X1 25X1 25X1

The modernization challenge centered on three problems. First, factories generally had outdated equipment that could not cope with new aerodynamic and 25X1

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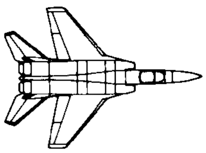
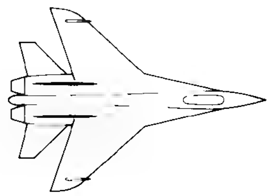
Figure 3
Soviet Aircraft: The 1980s Generation



MIG-29

An air defense fighter that carries advanced radar and air-to-air missiles, the MIG-29 entered production in 1982; the 1985 production rate is about six a month [redacted]



SU-27

An air defense fighter, the SU-27 is larger and more capable than the MIG-29. Although the 1985 production rate is about three a month, none had been deployed by mid-1985 because of problems with systems.

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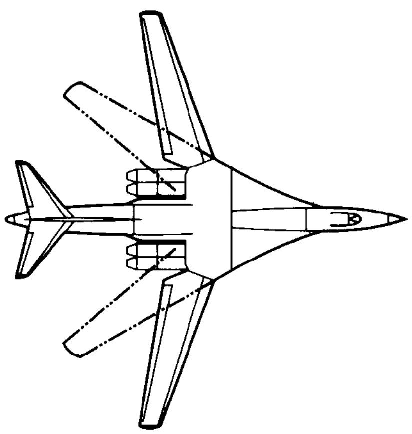
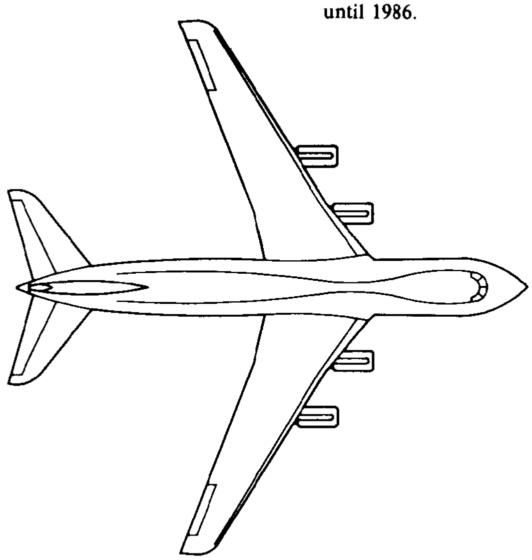


Blackjack

Although similar in configuration, the Blackjack is larger than the B-1. Five prototypes are participating in the test program. The Blackjack is not expected to enter production until 1986.



Condor

Condor is the world's largest airlifter. Three prototypes have flown, but the plane is not expected to enter production until 1986.

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The Ministry of Aviation Industry

The organization of the Ministry of the Aviation Industry impedes effective collaboration among researchers, designers, and producers. [redacted]

The Ministry has 16 major production facilities that manufacture fixed-wing aircraft, each of which is subordinate to a chief directorate responsible for the type of aircraft produced—bombers, helicopters, transports, or fighters. [redacted]

[redacted]

Bureaucratic obstacles are accentuated by geography. Almost all key research and design organizations are located in Moscow. Major plants are scattered throughout the Soviet Union. [redacted]

manufacturing technologies. Second, the level of technical support available to the plants was not sufficient for timely completion of complex manufacturing operations. Finally, correction of these deficiencies was hindered by investment practices that emphasized expansion of manufacturing facilities rather than improvement of production capabilities through renovation and retooling. [redacted]

Outdated Equipment

According to [redacted] Western visitors, Soviet aircraft plants were generally equipped in the 1960s with general purpose machine tools that could not machine the new harder metals efficiently. Visitors report that some resembled US plants of the 1930s and were equipped, for the most part, with machine tools that not only looked out of date in comparison with US technology, but often had indeed been manufactured in the 1930s. [redacted] in general, a lack of modern equipment, poor plant organization, indifferent management, disruptions to production, and few incentives to improve. [redacted] 25X1

Soviet machine tools were generally less productive, less capable, and less reliable than Western machine tools. For example, [redacted] the machine tools in aircraft plants tended to break down frequently. [redacted] as many as 40 percent of its machine tools may have been out of commission at any one time. Cutting tools reportedly were of such poor quality that they needed frequent sharpening and wore out quickly. [redacted] it was almost impossible for a Soviet machine to maintain cutting specifications during even an eight-hour shift; Western cutting tools maintained specifications for an entire month. [redacted] 25X1 25X1 25X1 25X1 25X1 25X1 25X1 25X1 25X1 25X1

The aircraft industry has tried to compensate for deficiencies in Soviet-made machine tools by manufacturing much of its own equipment. Most of these tools are made at a plant in Savelovo, north of Moscow. [redacted] the machines manufactured here appeared to be of higher quality than those available from the machine tool industry. Savelovo also produces equipment that is unique to the aircraft industry, such as very long spar mills and milling machines with extremely large beds for machining large structural workpieces. Nonetheless, despite its dedication to the aircraft industry, Savelovo has been unable to produce equipment as advanced as that being produced in the West. [redacted] 25X1 25X1 25X1

Lack of Technical Support 25X1

Modern manufacturing technology for the aircraft industry is complex and requires highly skilled technicians to install, operate, and support the specialized machinery involved. Often, the ability to make new processes work follows extensive experimentation in the manufacturing environment. New technological processes, especially, are frequently temperamental and difficult to operate correctly. [redacted] 25X1 25X1

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Figure 4
Major Aircraft Plants, Design Bureaus, and Institutes

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In the United States, aircraft companies have found that a team of technical experts may take as long as six months to a year to experiment with and adjust machines until they work to design specifications. In most cases, plants have in-house technical staffs to do this. The engineering staff that designed the aircraft and the plant's own manufacturing process departments are usually colocated with the plant. These organizations work closely together; it is not unusual to see engineers working alongside plant personnel. When outside help is needed, technical experts may be called in to work under contracts. [redacted]

In the Soviet system, the institutional separation of research and engineering from production is a strong barrier to improving manufacturing processes. Much technical support for manufacturing in the Soviet aircraft industry is provided by NIAT, a large independent research facility based in Moscow with branches in most cities with major aircraft plants. Westerners who have visited NIAT generally have been impressed with its capabilities, and Westerners [redacted] have indicated that it has done good work in developing manufacturing tools (for example, welding equipment). [redacted] employees of NIAT on assignment to the production plants design a complete work flow chart or process for each specific aircraft part or assembly. Some Westerners have commented that NIAT personnel appear to be more knowledgeable than manufacturing specialists in the plants. [redacted]

Although a part of the Ministry of Aviation Industry, NIAT is not formally connected to the production plants or even in the same chain of command. [redacted] meeting production goals is not primary for NIAT as it is for the plants. [redacted] NIAT often recommends the adoption of new manufacturing methods, but because it has no power to force the plants to adopt new methods many of its recommendations are ignored. [redacted] referred to NIAT as the "collective farm of wasted effort." US specialists who have either visited the Soviet Union or talked with the Soviets about the organization of the aircraft industry have also commented that the gulf between research and production is a significant weakness. [redacted]

NIAT's separation from production can also keep enterprising managers from adopting new methods. [redacted] 25X1 once a manufacturing process is established, the plant apparently has little authority to change it without NIAT's approval. The introduction of new processes is controlled entirely by the institutes and Moscow, and any change to approved manufacturing procedures has to be processed through NIAT. [redacted] 25X1

Misdirected Investment 25X1

We do not know the overall level and distribution of investment in the aircraft industry, but Soviet open-source writings, [redacted] 25X1 indicate that Soviet investment practices have hurt it. These practices, as confirmed by Soviet literature and emigres, indicate a bias in favor of erecting new facilities to expand capacity, rather than renovating existing equipment. Plants continue to maintain large quantities of old, technologically outdated machine tools and equipment. The US aircraft industry, in contrast, justifies acquisition of new machinery on a short-term basis, often to fulfill a single contract that may last only a few years. Furthermore, competitive pressures tend to force US aircraft manufacturers to replace machinery when it becomes technologically inefficient or obsolete. [redacted] 25X1 25X1 25X1

Ambitious plans for new facilities and Soviet financial and construction practices contribute to the low rate of renovation. Managers resist giving up any asset—especially equipment—that may help them meet objectives, in part because they are charged very low rates for holding capital.[1] Successfully keeping old equipment in place means that new facilities must be built to accommodate new equipment, which soaks up available funds. Soviet literature indicates that large-scale projects are more attractive to plant management than piecemeal projects because the responsibility can be lodged with a special construction 25X1 25X1 25X1 25X1 25X1 25X1

[1] The Soviet economy treats capital as a free good. Thus new plant and equipment are not put into operation as promptly as possible, and existing machinery is used —often through repeated repairs — for much longer periods than in the US and other Western economies. [redacted] 25X1 25X1 25X1

organization; modifying plans to account for downtime can be more easily justified, and financing is more likely to be provided from central government funds. Finally, according to a Gosplan official, lack of information about new equipment and lack of confidence in the ability of the machine tool industry to supply and support modern equipment also work against the acquisition of new tools. [redacted]

Modernization Program

The Soviets responded to the technological lag in the industry in the 1960s with a broad-based effort to improve aircraft plants' manufacturing capabilities. The program included the introduction of:

- Equipment for the machining and welding of titanium and other high-strength metals.
- Multiaxis numerically controlled machine tools for fabricating complex parts.
- Equipment needed for other manufacturing processes, such as bonding (fabricating parts by bonding layers of sheet metal together, rather than by attaching them with mechanical fasteners).

The Soviets launched efforts to learn how to fabricate structural parts out of nonmetallic composite materials, so as to allow designers to build lighter aircraft with improved performance. The USSR meanwhile bought large quantities of Western manufacturing equipment, either because equipment was not available from domestic suppliers or because the performance of the domestic equipment was judged to be inadequate. [redacted]

Upgrades of Plants

We believe that most, if not all, major facilities of the aircraft industry have been modernized to some extent since 1970. [redacted]

Some of the modernization has been tied to new production programs. Soviet procedures for the development of new systems usually require the accompanying development of dedicated tooling and equipment. For example, when the TU-144 supersonic transport was being introduced into production at the Voronezh aircraft plant in 1970 and 1971, Western visitors, as well as the plant director in a published interview, indicated that substantial quantities of new tools were installed—especially to machine the large number of titanium parts on the aircraft. These tools were not as capable as their Western counterparts. The titanium machining shop, for example, contained single-spindle, three-axis milling machines that resembled US automated milling equipment of the 1950s and 1960s. In the aluminum machine shop, however, visitors noted numerically controlled machines that were "essentially equivalent to ours." None of this equipment, however, incorporated features usually seen in US aircraft plants, such as computer-controlled and five-axis milling machines that could operate in three axes simultaneously. Still, these tools represented significant advances for the Soviets. [redacted] 25X1

Another example of modernization as part of a production program is the aircraft plant in Tbilisi, which appears to have been extensively modernized to produce the subsonic SU-25 Frogfoot ground attack aircraft both for Soviet forces and for export. Until 1979, this plant manufactured only trainer aircraft, and production was at a low rate. [redacted] the plant received many new machine tools that appear to be similar to the equipment installed in the aluminum machine shop at Voronezh. [redacted]

The Soviet press has also referred to aircraft industry modernization programs that appear to be part of a general upgrade of capabilities:

- A 1976 press article mentioned that aircraft engine Plant 19 in Perm', which produces engines for transports, "would be completely reequipped in

Table 1
Expansion Programs Under Way at Major Aircraft Plants

Location	Program	Year Operational	Production
Kazan'	Major expansion of fabrication and assembly floorspace. Will almost double size of plant.	First section complete 1985/86	TU-160 Blackjack bomber TU-22M Backfire bomber
Kuybyshev	New assembly and fabrication building. Increases plant area by almost 10 percent.	1986	TU-95 Bear H bomber TU-154M Careless transport
Saratov	New assembly building. Will increase size of plant by 11 percent.	1985	YAK-42 Clobber
Taganrog	New assembly building under construction. Will increase size of plant by 30 percent.	1986/87	TU-142 Bear F antisubmarine warfare bomber
Tashkent	New assembly and fabrication building under construction. Will increase size of plant by 35 percent.	1986	AN-124 Condor wing IL-76 Candid military transport
Voronezh	New assembly buildings. Will increase plant by 15 percent.	1986	IL-86 Camber transport IL-96 transport
Komsomol'sk	New fabrication building. Increases plant by almost 30 percent.	1981	SU-27 Flanker fighter
Moscow	New fabrication and assembly buildings. Will increase plant area by 18 percent.	1986	MIG-29 Fulcrum fighter

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program-controlled and other sophisticated machinery to replace the present lathes. The reequipment is expected to treble the output of plane and helicopter engines."

- A 1978 article indicated that the airframe plant in Kuybyshev, which manufactures the TU-154 civil transport, was being retooled and modernized. According to the article, the modernization program would increase the productive capacity of the plant two and a half times.

- A 1982 article described the reequipment of the aircraft engine plant in Zaporozh'ye, the only plant now known to be producing high-bypass turbofan engines.

- A February 1983 *Pravda* article outlined the modernization of the Kuybyshev aircraft engine plant, which produces the engines for the MIG-25 Foxbat, TU-144, and several other late-model aircraft. This article, like that about the Kuybyshev airframe plant, emphasized that modernization would greatly expand the plant's productive capacity. [redacted] 25X1

Finally, the Soviets have accomplished substantial modernization as they have expanded assembly capacity. [redacted] 25X1 [redacted] the Soviets frequently erect a new production facility for new systems and equip it with the best available technology. The eight plants that are to expand the most in the mid-1980s are charged with production of advanced aircraft (see table 1). [redacted] 25X1 [redacted] new equipment, including a large press and several autoclaves purchased from the West, is being installed in the new Tashkent facility (figure 5).[2] [redacted] 25X1

[2] Autoclaves are large vessels that are used to cure composite materials at both high temperatures and pressures. [redacted] 25X1

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The Soviets are also building a new airframe plant in Ul'yanovsk that, when completed, will be their most modern. We think this is the plant mentioned repeatedly by Soviet aircraft production specialists during their visit to the United States in 1973. They had often referred to a requirement for a new production facility for manufacturing wide-bodied aircraft that would incorporate Western advanced manufacturing methods and equipment. Construction of the Ul'yanovsk plant was begun in 1977, and, even though only partially complete, it is already the Soviets' largest aircraft plant. [redacted]

The construction at Ul'yanovsk represents a significant part of the Soviet aircraft industry's commitment to modernization. Indeed, analysis of expansion trends in the industry suggests that most of its capital investment funds since the mid-1970s have been spent on Ul'yanovsk. For example, the average amount of new production floorspace being added annually to existing plants has been declining since the construction at Ul'yanovsk began. Of the new production floorspace that will be added to the industry in the 1980s, Ul'yanovsk will probably contain more than 50 percent. [redacted]

Most of the other seven airframe plants probably have also been modernized to some extent. All were expanded in the early 1970s, at the same time as the introduction of new production programs that probably required at least limited improvements in manufacturing technology. Tbilisi was probably among the last to be modernized because it is a small plant that appeared to have a relatively low priority then. [redacted]

Development of Composite Manufacturing Capability

Aircraft structures made of composites are stronger and lighter than those manufactured with comparable metal structures. Thus, composites afford a combination of greater payload, range, and maneuverability than conventional materials—according to some US manufacturers, at no increase in cost. Composites have been under development in the United States since about 1970; manufacturers are now using them for major portions of aircraft in production. McDonnell Aircraft Company, for example, is making large sections of the AV-8B vertical short takeoff and landing fighter (including the entire wing) out of composites. Collectively, composites account for 26 percent of the weight of the AV-8B structure, and McDonnell forecasts that composites will account for as much as 40 percent of the weight of its next fighter. According to a US publication, one Boeing study predicts that, by 1995, two-thirds of Boeing's commercial aircraft structures will be manufactured from composite materials. [redacted] 25X1

Manufacturing aircraft components from composite materials requires new processes that differ greatly from traditional metalworking techniques, and these processes require substantial investment in new plant and equipment. Some types of traditional metal-forming machines such as stretch formers, hydropresses, drop hammers, and milling machines either are not required or are used very little. New types of required production equipment include autoclaves, refrigerators, clean rooms, computer-controlled cutting and layup machines, and X-ray and other types of nondestructive testing devices.[3] [redacted]

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A review of airframe expansion projects undertaken in recent years suggests that the Soviets are making a major commitment to the development of a composite manufacturing capability throughout the industry (see inset, "Use of Nonmetal Composite Materials in Soviet Aircraft," and figure 4). Major additions to both the Tashkent and Voronezh airframe plants have been identified as probable composite facilities.[4] The airframe plant in Moscow that is building the Fulcrum also has a new composite manufacturing capability [redacted] 25X1

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Composite manufacturing facilities have been identified at both the Mil and Kamov helicopter design bureaus and at the Rostov helicopter plant. We believe other facilities probably have been, or are in the process of being, outfitted for composite production, but we have not yet identified them. [redacted] 25X1

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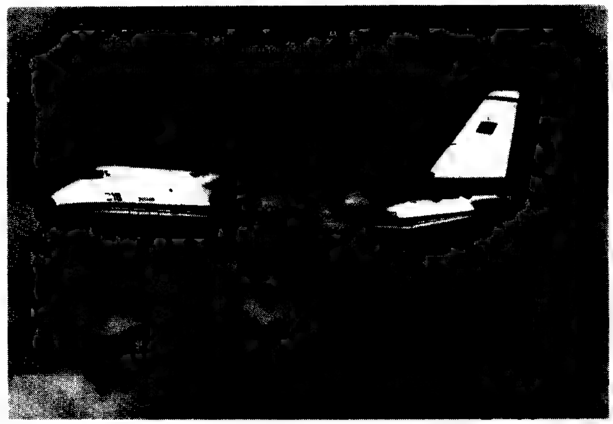
[3] Because of the requirement of a pristine environment, many US companies prefer to perform composite manufacturing processes in new buildings. [redacted] 25X1

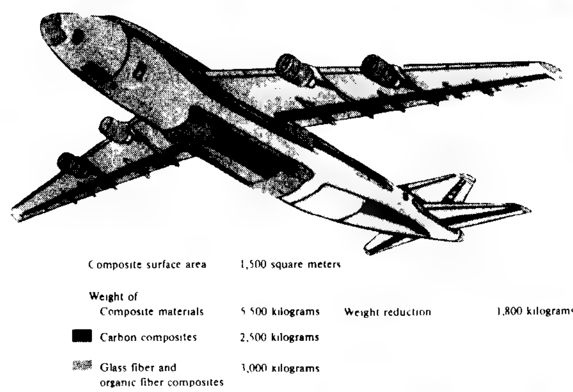
[redacted] 25X1

Use of Nonmetal Composite Materials in Soviet Aircraft

The USSR has made considerable progress in applying composites. According to [redacted] 25X1 *reporting and Soviet publications, nonmetal composite materials have been used on the TU-144, AN-22, AN-24, AN-28, and AN-72 transports; later versions of the MIG-25 fighter; and the TU-22M Backfire bomber. Because these aircraft were designed before advanced composites were available for widespread application, most of these applications probably were intended either to test the material or to gain operational experience with composites. We believe the IL-86 transport, which entered production in 1978, represents the first major use of composites in the production of Soviet aircraft.* [redacted] 25X1
[redacted] *the floor of the passenger compartment of this wide-bodied transport is made of composites.* 25X1
[redacted] 25X1

Aircraft recently entering production or still in development are using increased amounts of composites. For example, the AN-124 Condor heavy airlifter contains about 5,500 pounds of advanced carbon composites, according to data released by the Soviets at the 1985 Paris Air Show. The applications on the Condor are secondary structures, such as landing gear doors, wing and fuselage fairings, and the rear cargo doors. [redacted] 25X1
[redacted] *10 to 20 percent of the structure by weight of the MIG-29 is made of composite materials—including the vertical and horizontal stabilizers, ailerons, flaps, stringers, various access doors, and the wing-fuselage splice. As on the Condor, most of these applications appear to be composite skins bonded to honeycomb cores.* [redacted] 25X1





Composites on the AN-124 Condor. *The use of composites on the Condor is the most extensive to date for any Soviet aircraft. The quality of workmanship and level of sophistication displayed in the photographs, however, are well below Western standards.* [redacted] 25X1

[redacted] 25X1

Increased Use of Imported Machine Tools
Trade statistics indicate that the Soviet Union is the world's largest importer of machine tools. In the aviation industry, Western machine tools appear to have been used primarily because of their superior capabilities and improved efficiency rather than to supplement or replace those domestically produced. According to a 1982 article in the French press (which quoted the director of the Voronezh aircraft plant), less than 5 percent of the machine tools in Soviet aircraft plants is foreign. [redacted]

[redacted] because of the need to modernize the aircraft industry, the Soviets are trying to acquire more foreign machine tools [redacted]

Even in limited quantities, Western equipment may have a significant impact on Soviet production capabilities. Its use enables the industry to produce higher quality parts more efficiently than domestically manufactured production equipment would permit. Most of this is highly efficient numerically controlled or automated equipment. [redacted] the Swedish presses could do in 15 minutes what it would have taken Soviet-manufactured equipment three or four days to perform. [redacted]

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Program Falls Short

Soviet efforts to catch up with Western aircraft production technology have been hindered by dramatic advances in the West. [redacted] important, state-of-the-art manufacturing technologies have a lifetime of about 10

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years and then become obsolete even though equipment may still be in good operating condition. The Soviets themselves have published reports indicating that modern machine tools lose their technological advantage in about seven to seven and a half years. [redacted]

Continuing Emphasis on New Construction

Despite this technological imperative, the Soviets continued through the 1970s to use most investment funds throughout the industry for new construction rather than for the replacement or upgrading of existing equipment. A recent *Pravda* article—praising the manager of the Rybinsk aircraft engine plant for bucking the trend—indicated that only 39 percent of total capital investment for the USSR is used for equipment purchases, while the rest goes to construction of new floorspace. Other Soviet publications indicate that, of the investment funds that are spent on machinery and equipment purchases, 70 to 80 percent is spent on the purchase of equipment to fill the new floorspace, while only 20 to 30 percent is spent on equipment to replace existing stocks. [redacted]

As a result, according to Soviet literature, the annual renewal rate for manufacturing equipment in the USSR is only about half that in the United States and about one-third that in West Germany. Although Soviet publications indicate that about 36 percent of the total Soviet machine tool stock has been acquired since 1975, the annual rate of renewal of existing stocks is low—probably less than 3 percent, [redacted] At this rate, perhaps 30 to 40 years would be required to bring all existing equipment in the Soviet metalworking industries to the current state of the art. In addition, the aircraft industry has also been plagued with poor machine tool quality, slow acceptance of composites, and poor technical support. [redacted]

Poor Machine Tool Quality

Even the latest types of Soviet machine tools do not appear to be as reliable or to be manufactured to the same standard of quality as Western machine tools. [redacted] the Italians, who have imported large quantities of Soviet machine tools, complained that the bearings and shafts of the Soviet tools wore rapidly and, as a result, were not accurate. Other Westerners who have purchased Soviet machine tools have reported similar experiences. The aircraft industry apparently suffers from the same problem. [redacted] the Soviets are having problems with the industrial drilling and boring tools used by the aircraft industry. As a result, workmanship of various aircraft parts has been poor, often causing the parts to crack under severe stress. [redacted]

Slow Acceptance of Composites

Despite the capability for composite manufacturing at some plants, elements of the aircraft industry seem to be resisting reliance on composites. [redacted] only the Antonov and Mikoyan Design Bureaus, designers of the Condor and the MIG-29, are enthusiastic about composites. Other design bureaus were said to be afraid of working with them or unwilling to pay the price for the production equipment needed to produce composite parts. [redacted]

[redacted] most composite structural parts are being fabricated in Moscow by the Scientific Research Institute for Aviation Materials (VIAM). [redacted] the production plants are running into difficulties or that not enough plants have been equipped with necessary plant and machinery. VIAM reportedly fabricates standard shapes, such as tubes, clips, plates, and angles, that are neither tailored to nor conform to specific aircraft. These parts are then shipped to production facilities where they are assembled. This method differs from that generally used in the West, where parts are designed for specific applications on each aircraft by varying the shape and thickness to meet the exact requirements of the installation. [redacted] the inspection procedures the Soviets say they are using are inferior to the ones used in the West. And the Soviets continue to rely on the West for composite manufacturing equipment, some manufacturing materials, and on process technology. If the West failed

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to provide this equipment, the Soviet composite effort would be severely hampered.

Poor Technical Support

Although the Soviets recognize the importance of improving the quality of the technical support available to aircraft plants, the level of this support still does not meet Western standards. For example, in a recent *Pravda* article, the Director of the Special Design Production Office of the Ufa Aviation Institute said that the creation of flexible machining centers in the industry was "unthinkable" without better coordination between the organizations that build the new equipment and the plants that will operate it. His recommendation that engineers from the machine tool plant be transferred to the aircraft plant would help, but US experience indicates that solution would be only partial. The Soviets have not instituted or announced plans for more fundamental changes that would shift technical resources within the Ministry of Aviation Industry, such as the subordination of elements of scientific research institutes to the plants.

Outlook

Since the 1960s, modernization of Soviet airframe plants has supported development of a number of aircraft— particularly the AN-124, the TU-160, the SU-27, and the MIG-29—that are much more technologically advanced than their predecessors. Nevertheless, they are at best roughly comparable to Western aircraft that were introduced much earlier. For example, the AN-124 flew 14 years after the C-5A; preliminary examination of the AN-124 displayed at the 1985 Paris Air Show indicates that it is little more advanced than the C-5A. The TU-160 flew eight years after the B-1, and the SU-27 and MIG-29 flew about five years after their Western counterparts.

This lag in systems technology, along with fragmentary direct evidence of manufacturing technology, suggests that Soviet aircraft manufacturing capabilities in the mid-1980s are roughly comparable to those of US industry about five to 10 years earlier. Even recent Soviet work on substantially new and high-priority aircraft suggests a slow rate of renovation. 25X1
For example, to produce the IL-86 Camber (their first wide-body transport) the Soviets now use the same machinery and manufacturing processes that were installed at Voronezh in the late 1960s for the TU-144 supersonic transport program. According to the director of the plant: "We invested almost nothing to start production [of the Camber]. We used practically all of the equipment and the 200 technological processes developed for the previous program [the TU-144]." (However, the new building for composite production was used.) Moreover, the pattern of advance appears to be sporadic, which suggests that the level of Soviet production technology remains more uneven than would be typical of a Western aircraft industry. 25X1 25X1

Manufacturing capabilities also still seem to be constraining advances in Soviet aircraft design. In the mid-1970s a Soviet designer complained: "The US designer is a 'strong man,' but, in the USSR, manufacturers say that they cannot meet their goals, so he [the designer] must change [his design]." The IL-86 illustrates the continuing impact of manufacturing technology (see inset, "The IL-86 Wide-Bodied Transport: Impact of Available Manufacturing Technology"). These deficiencies have helped prevent the Soviets from closing the gap with US aircraft technology—their stated goal. 25X1 25X1

Continuing rapid advances in Western aviation suggest that ongoing Soviet modernization will be insufficient to narrow the gap through the 1990s. The next generation of US fighters, for example, will incorporate a number of advances that will provide significantly better performance:

- Short takeoff and landing capability to enable the fighter to operate from runways as short as 1,500 feet.
- Aerodynamic and structural characteristics that will enable the aircraft to maintain higher speeds throughout maneuvers. 25X1
- Reduced radar cross sections and reduced infrared signatures for increased survivability.
- Improved fire-control systems capable of detecting and tracking enemy aircraft at longer ranges.

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The IL-86 Wide-Bodied Transport: Impact of Available Manufacturing Technology

The tooling that is installed at Voronezh probably influenced the design of the IL-86. The IL-86 contains a higher percentage of titanium than most subsonic civil transports; it is about 15 percent of its structural weight, according to Soviet publications. Because titanium is expensive and difficult to fabricate, Western civil transports normally have only a small amount of titanium—2 to 4 percent. It is used only as a high-strength fastener or in locations where it is required because of its ability to withstand high temperatures. Soviet publications describing the TU-144 supersonic transport, which preceded the IL-86 in production at Voronezh, indicate that it contained a high percentage of titanium, about 18 percent of its structural weight—which is normal for supersonic aircraft. The fact that the titanium content of such dissimilar aircraft is about the same is not in itself conclusive evidence, but it raises the possibility that the decision to use so much titanium in the design of the subsonic IL-86 was, at least in part, influenced by the availability at Voronezh of machine tools and other manufacturing equipment that could handle titanium.

- Improved maneuverability and acceleration as a result of the introduction of new features such as variable-geometry wings that can change their shape in flight.[5]
- Improved flight-control systems that lessen the pilot's lower workload and improve aircraft performance.

These improvements will be based in part on ongoing advances in US manufacturing technologies. Aircraft structures using advanced types of stronger and more flexible composites will permit mission-adaptive wings; new manufacturing processes will permit superplastic forming and diffusion bonding of titanium and other hard metals; powdered metal developments will afford better alloys than those available at present; and new metals and construction techniques will permit development of vectored thrust nozzles for fighter engines. Moreover, computer-aided design will help to integrate the design and manufacturing processes to a greater extent, which will increase manufacturing efficiency and aid in the design of lighter and more accurate parts. In addition, the new electronic systems and controls will also improve aircraft performance. 25X1

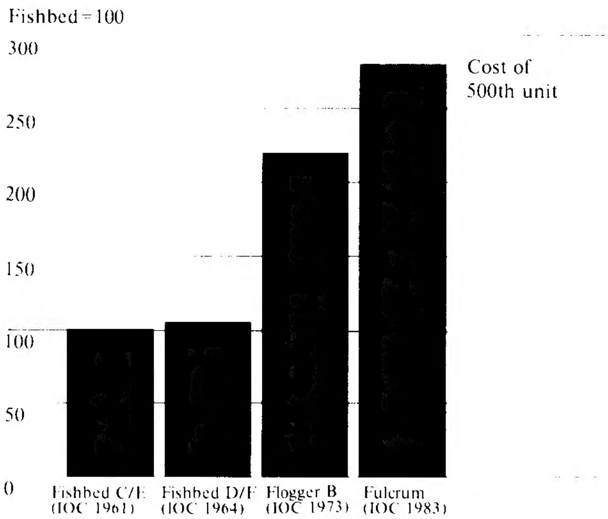
These Western advances will require major investments in facilities and will capitalize on experience gained since the mid-1970s. Western manufacturers will continue to experiment with advanced aeronautic and manufacturing technologies that will yield improved performance as the Soviets are beginning to master applications of the basic technologies, such as composites. Each Western advance represents a marked step forward, but comes only after a considerable investment in learning. 25X1

The deliberate and discontinuous nature of Soviet aircraft plant modernization is likely to keep the technological capabilities of Soviet plants at a level below that in the West. We do not believe the USSR 25X1 has substantially improved the level of technical support to aircraft enterprises, and, given the competition for investment resources, planners are unlikely to generate the necessary capital improvements to bring Soviet industry up to the West's level. The large Western investments planned for new manufacturing technologies further support our belief that it will be 25X1 difficult for the Soviets to maintain their relative position, let alone catch up with the West. 25X1

Lagging modernization will also affect the airframe manufacturing industry's efficiency. The Soviets are concerned about the need to improve industrial productivity; Gorbachev has announced that almost all future increments in output will have to come from productivity gains. These gains will depend in part on the widespread adoption of efficient manufacturing methods that include computer-controlled machinery, robotics, and product data bases common to all of the

[5] Variable-geometry wings include such features as variable sweepback, variable camber, and mission-adaptive wings. A mission-adaptive wing is able to vary its cross sectional shape in flight to better fit performance variables such as lift and drag to actual flight conditions. 25X1

Figure 6
Rising Unit Costs of Soviet Aircraft[a]



[a] Fighter aircraft with comparable missions.

Note: The costs displayed above reflected indexed 1982 dollars and are not actual Soviet expenditures. They are estimates of what it would cost to produce these Soviet systems in a US factory using US wage rates, material costs, and equipment operating factors. Although this chart illustrates the increase for one type of fighter aircraft, other aircraft are experiencing comparable increases.

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design bureaus. Without widespread introduction of new manufacturing technologies, Soviet aircraft production will remain highly labor intensive. Thus, recent trends toward lengthening aircraft production times and higher unit costs probably will continue (see figure 6). 25X1

Without a strengthened effort to modernize their plants, the Soviets are unlikely to be able to field aircraft that can keep up with advancing Western capabilities. For example, a new Western fighter incorporating improved features such as thrust vectoring, mission-adaptive wings, lightweight yet stronger structures, and incorporating a low-observable design would put the Soviets at a severe disadvantage in combat. The technologies that make these developments possible include extensive use of composites for primary structures, improved high-temperature yet lightweight materials, intricate machining by five-axis machine tools, and improved electronic controls. The Soviets' probably slow progress in these technologies will impair even strong efforts to close the gap with the West in aircraft performance. 25X1

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